

# Diagnosis of the Warm Bias Exhibited in CMIP5 AMIP Climate Simulations over ARM SGP site

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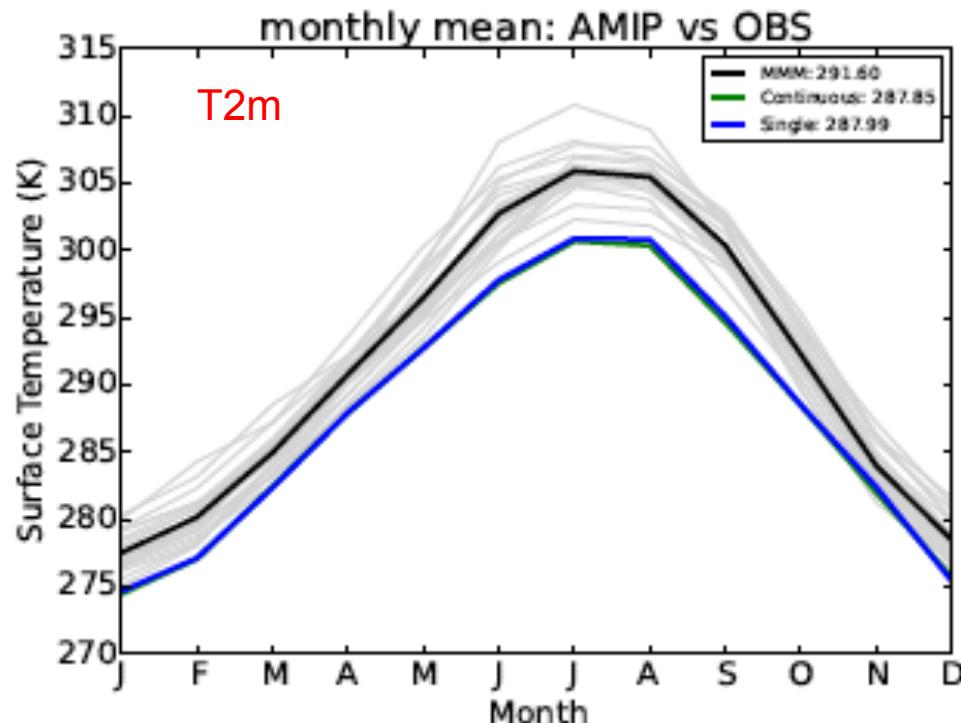


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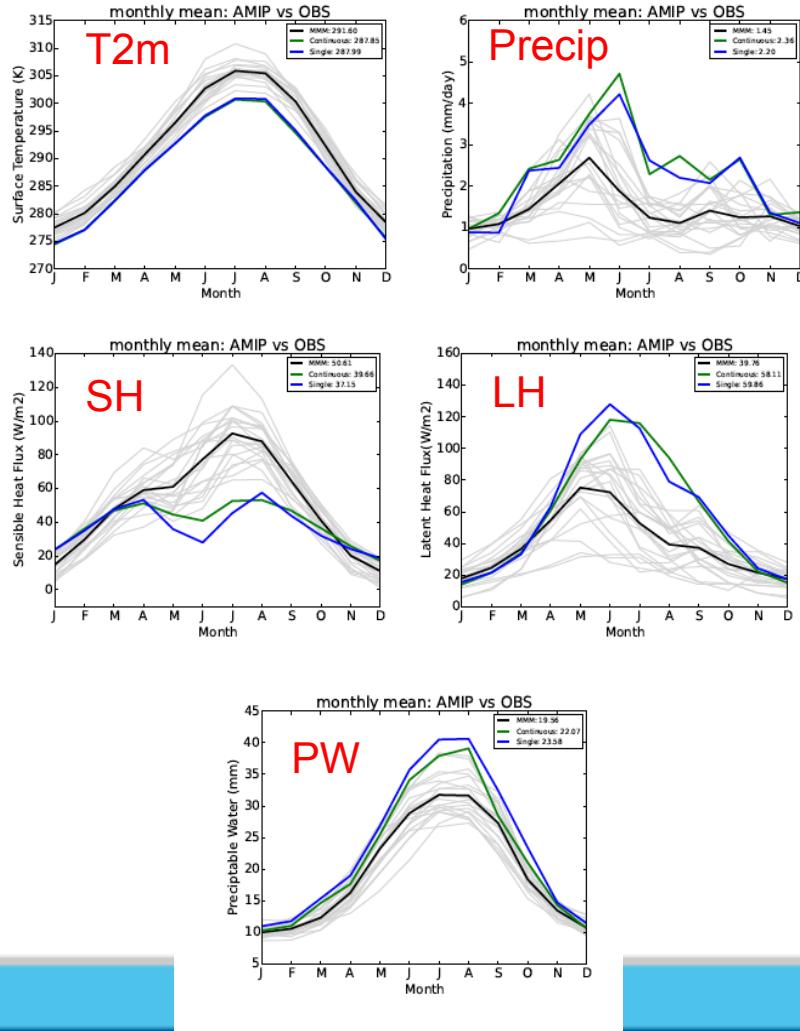
# Warm bias exhibited in CMIP5 AMIP Climate Simulations over ARM SGP site



- **AMIP simulation:**  
Eliminate SST bias introduced by coupled simulations
- Warm bias exhibits year around for most CMIP 5 models.  
~ 3.6 K in Annual mean  
~ 5.2 K in JJA
- Black: Multi-model mean  
Green: Continuous forcing  
(Variational analysis)  
3x3 Deg. domain mean  
Blue: Single point at central facility  
(ARMBE)



# Statistical Summary of Bias patterns in Climate Simulation over SGP

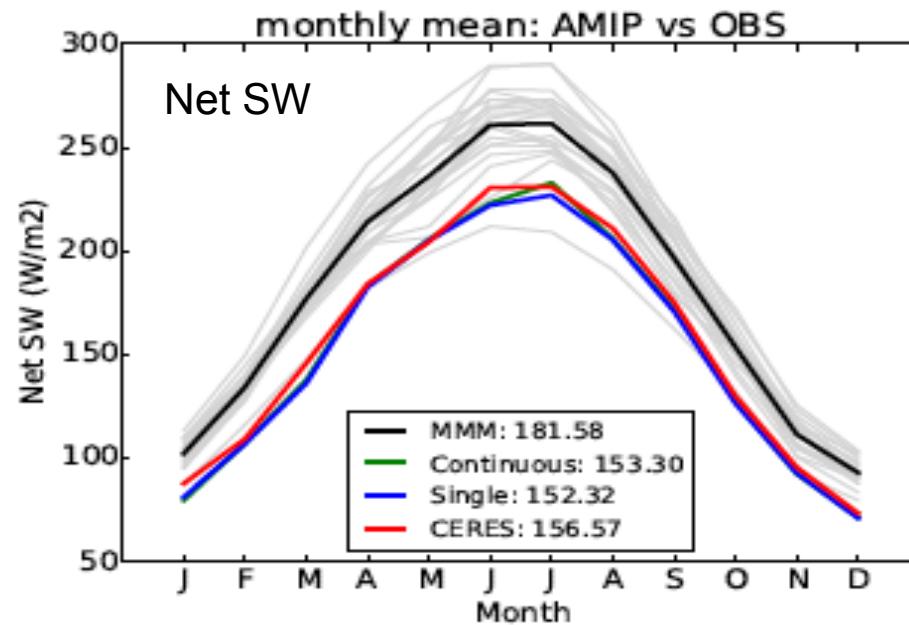


- Surface is too warm and dry.  
Bias is the highest during summer.
- Sensible heat is over-estimated  
latent heat is under-estimated in summer
- Precipitation peak bias
- The atmosphere column is too dry



# What contribute to the T2m bias?

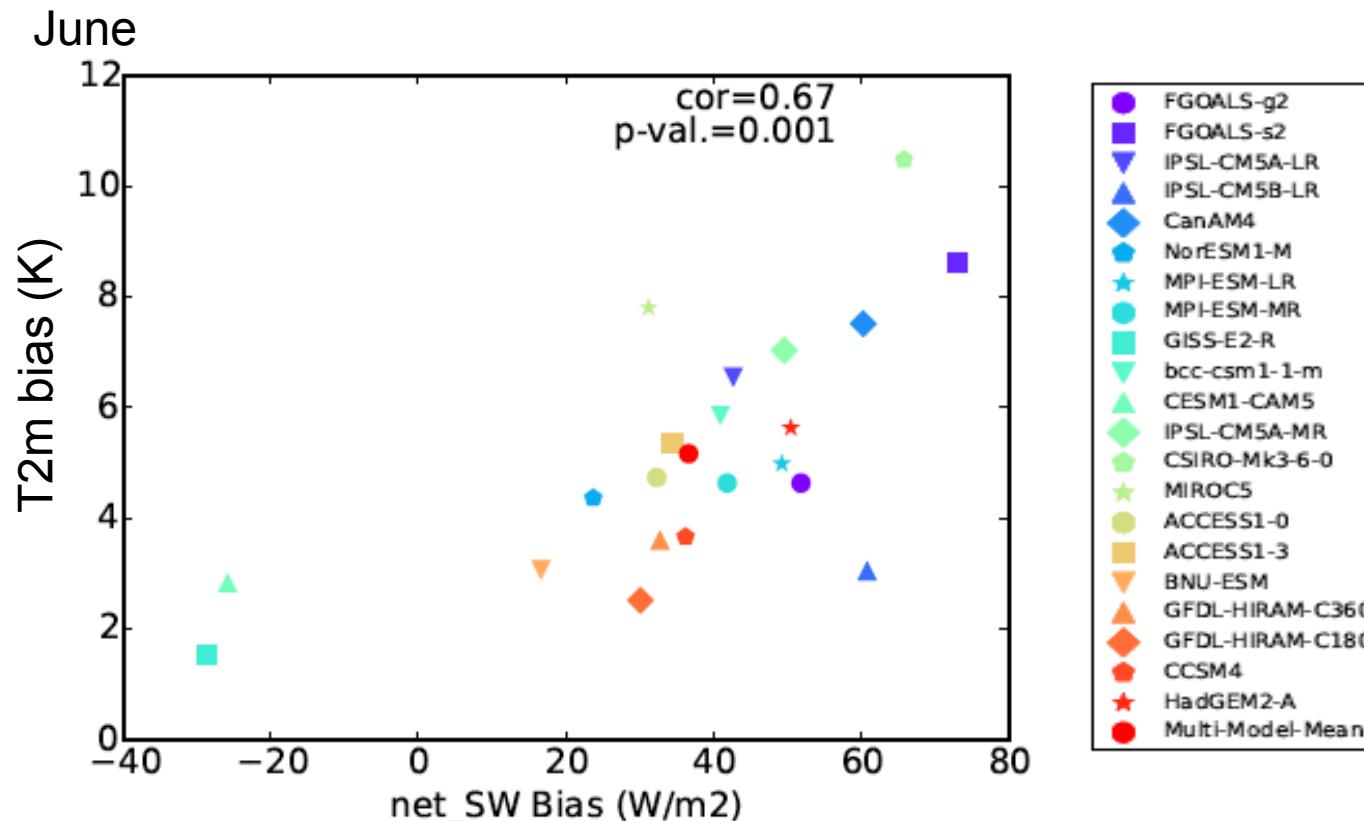
Contribution of solar radiation error at surface



Based on both **CERES (Red)** and **ARM data (Blue and Green)**,  
models have strong net solar radiation bias (25~29 W/m<sup>2</sup> in annual mean)



# Net SW bias correlates to T2m bias across models



# Partition the surface net SW error

$$\begin{aligned} \text{Net-SW error} = & (1 - \alpha_{\text{mod}}) * \text{SWDN clr,error} & \text{SWDNclr error} \\ & + (1 - \alpha_{\text{mod}}) * \text{SWDN cre,error} & \text{SWDNcre error} \\ & + (\alpha_{\text{mod}} - \alpha_{\text{obs}}) * (\text{SWDN clr} + \text{SWDN cre}) & \text{Albedo error} \end{aligned}$$

Net SW error attribution (JJA mean):

CMIP5 Mean -Observation	Net-SW error (Wm-2)	Albedo error (Wm-2)	SWDN-clr error (Wm-2)	SWDN-cre error (Wm-2)
Based on ARM	32.68	6.26	4.84	21.54
Based on CERES	29.15	0.86	14.67	13.62



# ARM vs CERES vs models

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- The Radiative Flux Analysis product from ARM:  
Clear-sky fluxes are derived for identified clear-sky, empirical cosine fit based on solar angle to generate continuous data stream. **It reflects ACTUAL Clear-sky fluxes.**
- CERES and models:  
Clear-sky fluxes are calculated by removing the cloud but retaining aerosol and water vapor at cloudy time. Clear-sky fluxes are lower than ACTUAL clear-sky values.  
**In order to evaluate climate models, CERES surface product is more suitable under definitional ground.**

→

CMIP5 Mean -Observation	Net-SW error (Wm-2)	Albedo error (Wm-2)	SWDN-clr error (Wm-2)	SWDN-cre error (Wm-2)
Based on ARM	32.68	6.26	4.84	21.54
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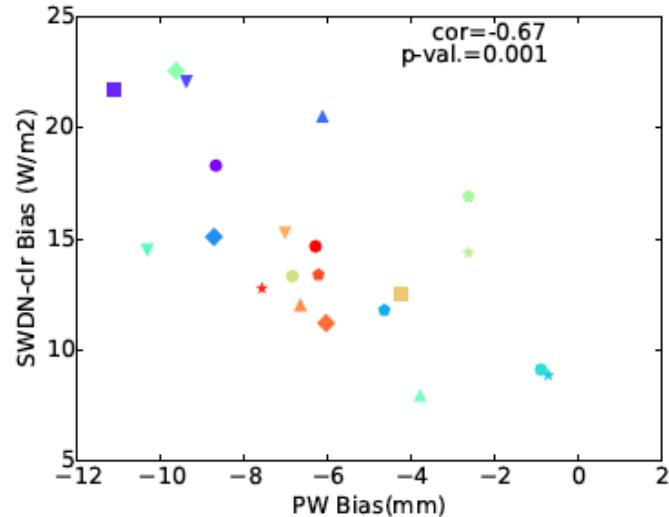
Thanks to Seiji Kato, David Rutan and Chuck Long for helping to understand.



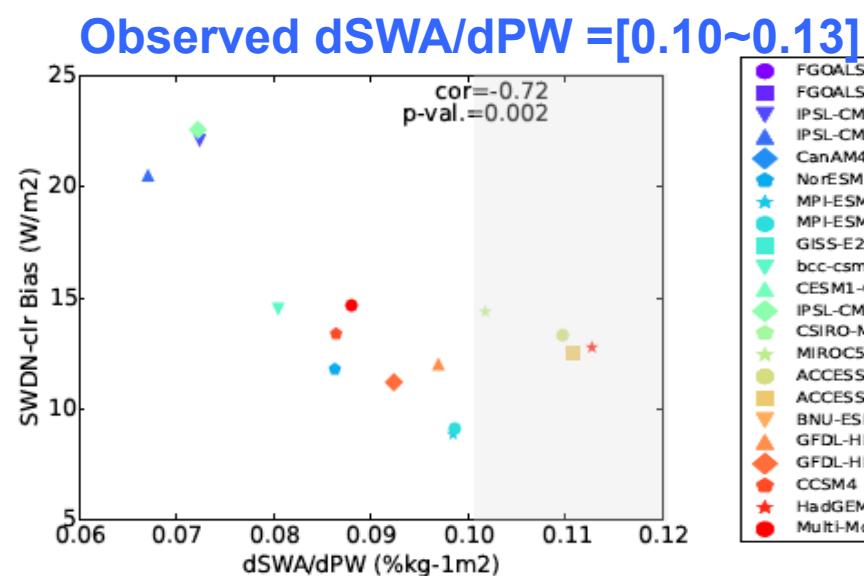
# PW and [dSWA/dPW] errors contribute to clear-sky SWDN error

PW : Precipitable water

dSWA/dPW: SWA (SW absorption) sensitivity to PW variation



PW bias (mm)



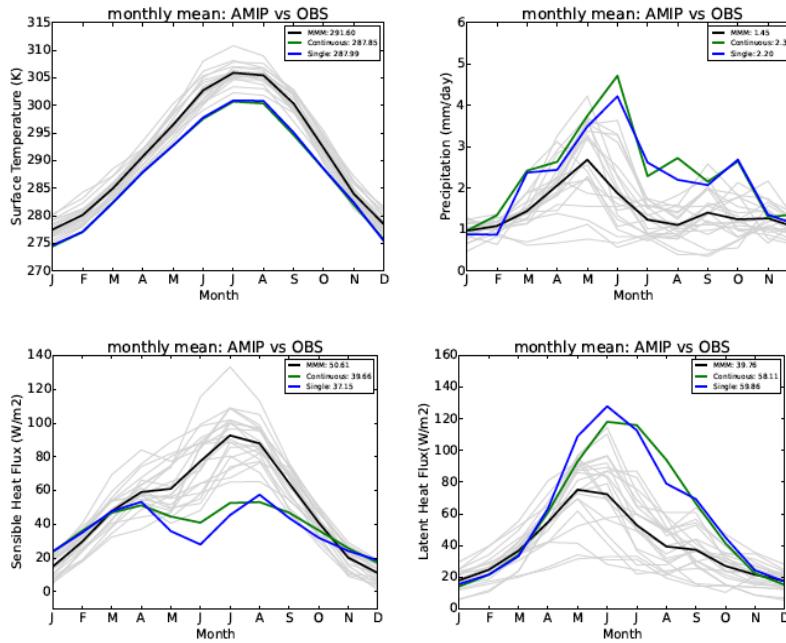
dSWA/dPW (%kg<sup>-1</sup>m<sup>-2</sup>)

radiation transfer scheme deficiency  
(DeAngelis et al. 2016)

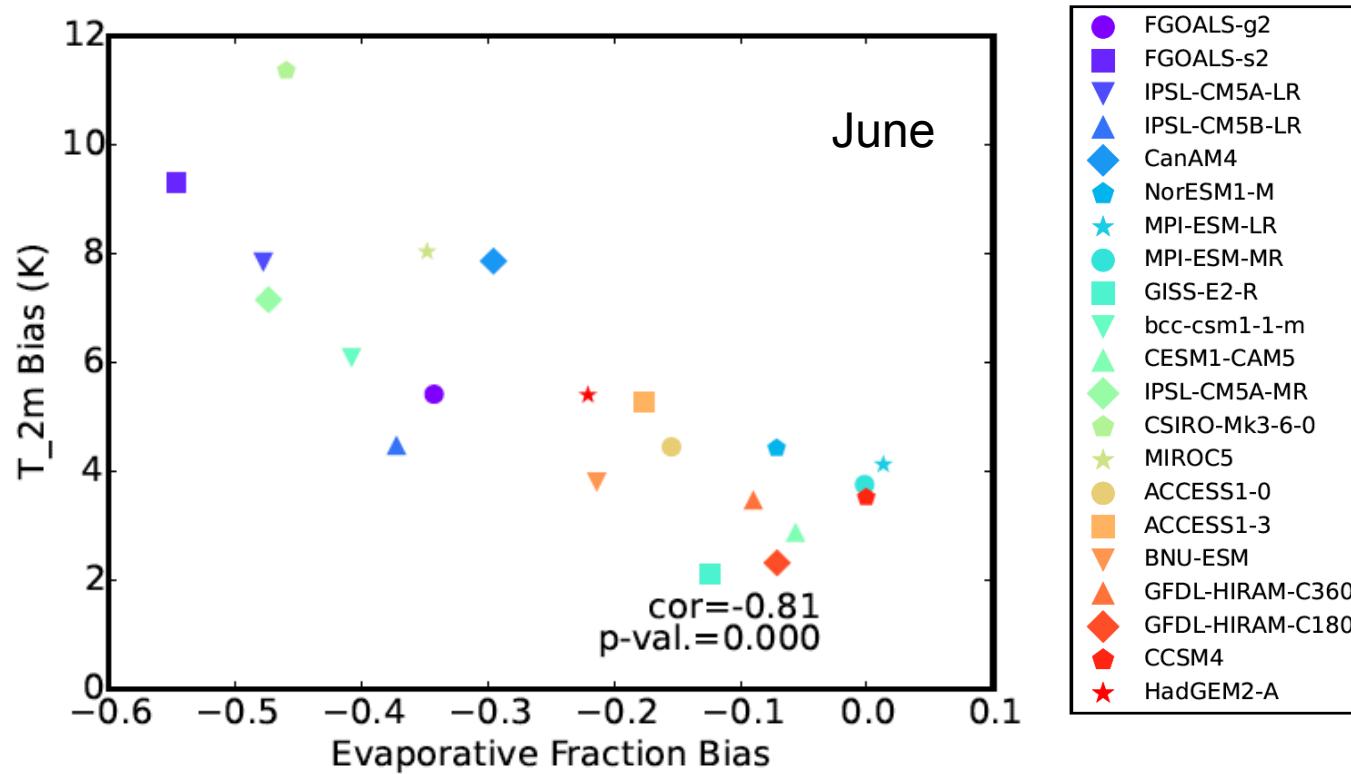


# What contribute to the T2m bias? Contribution from hydrological processes

Systematic bias in summer rainfall and evaporation is found in all GCMs.  
Precipitation and evaporation are too low.



# EF correlates to T2m bias across models

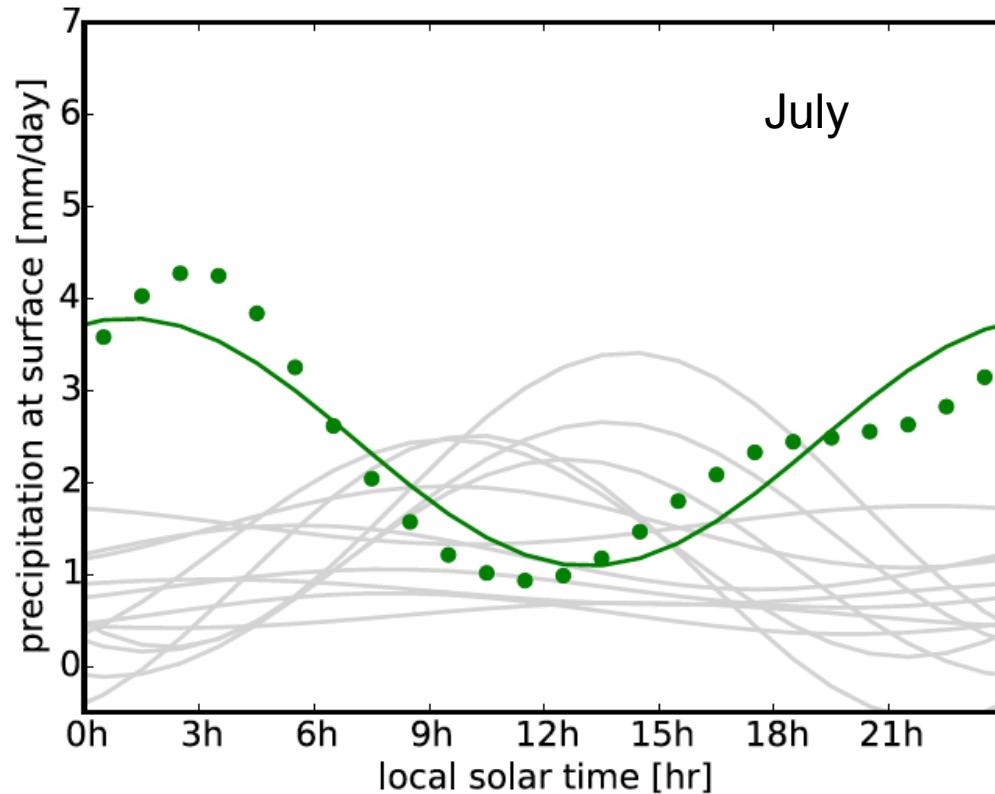


the partition of available energy at  
the land surface:  $\text{EF} = \text{LH}/(\text{SH} + \text{LH})$



# Diurnal cycle of precipitation

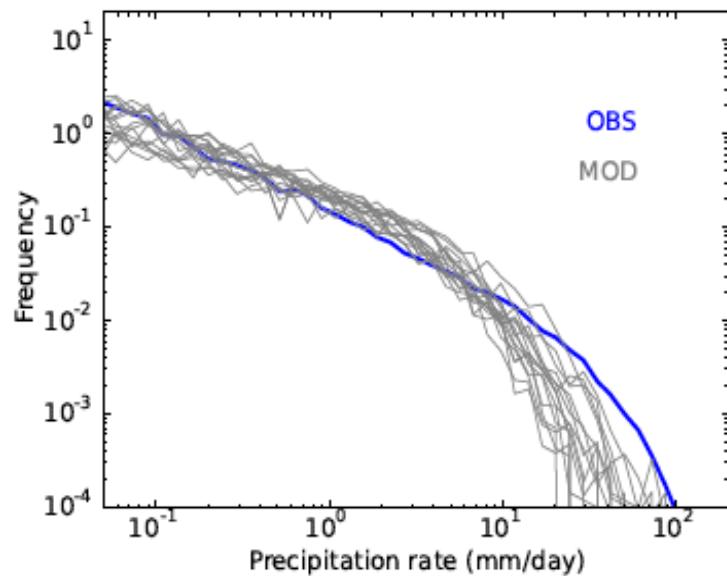
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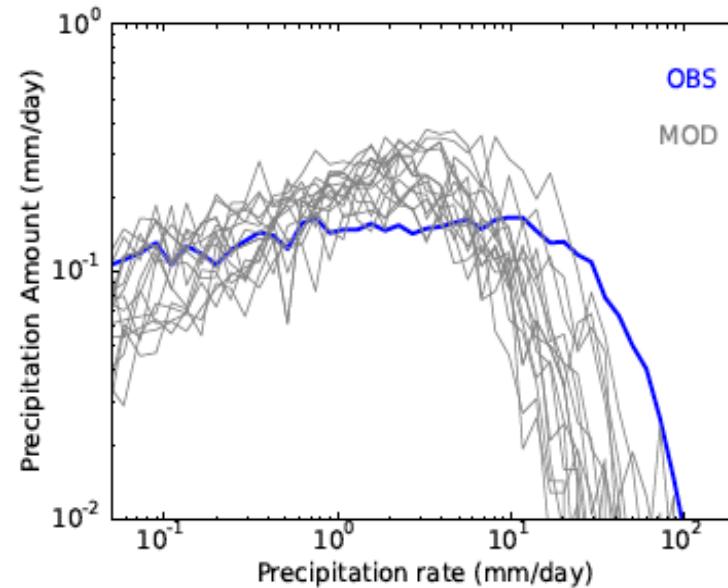
Models miss the nocturnal peak that is associated with eastward propagating convective episodes



# PDF of precipitation



(a) Precipitation Frequency: JJA



(b) Precipitation Amount: JJA

- Models overestimate moderate precipitation occurrence, but underestimate light and heavy rainfall occurrence.
- This may relate to deficiencies in convective schemes in models



# Summary and Discussion

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- Warm bias over ARM SGP site is found in CMIP5 AMIP type of simulations
- Over-estimated net solar radiation and under-estimated Evaporative Fraction are responsible for the bias creation
- Both cloud radiative effect and clear-sky errors are important components in net solar radiation error\*
- Process-oriented diagnosis using higher frequency model outputs
  - separate day time and night time processes
  - analyze what types of precipitation errors (nocturnal heavy rainfall? ) that contribute most to the warm bias
- Large-scale circulation bias is inevitable: CAPT is a better tool to eliminate the large scale forcing bias and focus on the local physical processes



# Extra slides

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# Prioritize the surface net SW error

$$\begin{aligned}
 \text{Net-SW error} &= (1 - \alpha_{\text{mod}}) * \text{SWDN clr,error} & \text{SWDNclr} & \text{error} \\
 &+ (1 - \alpha_{\text{mod}}) * \text{SWDN cre,error} & \text{SWDNcre} & \text{error} \\
 &+ (\alpha_{\text{mod}} - \alpha_{\text{obs}}) * (\text{SWDN clr} + \text{SWDN cre}) & \text{Albedo} & \text{error}
 \end{aligned}$$

Based on CERES\_EBAF:

Model	Net-SWDN error (Wm-2)	Albedo error (Wm-2)	SWDN-clr error (Wm-2)	SWDN-cre error (Wm-2)
FGOALS-g2	19.11	-9.64	18.31	10.51
FGOALS-s2	38.18	-7.93	21.76	24.32
IPSL-CM5A-LR	26.86	0.07	22.09	4.79
IPSL-CM5B-LR	41.04	-1.48	20.53	22.07
CanAM4	41.78	-1.03	15.10	27.53
NorESM1-M	35.49	6.23	11.80	17.60
MPI-ESM-LR	19.46	-7.52	8.87	18.13
MPI-ESM-MR	17.20	-7.48	9.12	15.55
GISS-E2-R	-20.10	0.49	13.34	-33.99
bcc-csm1-1-m	18.24	-8.61	14.50	12.30
CESM1-CAM5	8.21	5.42	7.96	-5.11
IPSL-CM5A-MR	40.46	3.58	22.58	14.28
CSIRO-Mk3-6-0	54.00	10.08	16.92	26.76
MIROC5	36.65	7.67	14.39	14.64
ACCESS1-0	30.93	2.49	13.33	15.23
ACCESS1-3	44.42	10.77	12.55	21.25
BNU-ESM	56.40	20.63	15.28	20.44
GFDL-HIRAM-C360	22.81	0.03	12.03	10.81
GFDL-HIRAM-C180	12.97	-7.02	11.21	8.74
CCSM4	34.80	2.02	13.39	19.52
HadGEM2-A	33.21	-0.74	12.78	21.10
Multi-Model Mean	29.15	0.86	14.67	13.62

With out GISS : 31.6    0.88    14.73    16.00

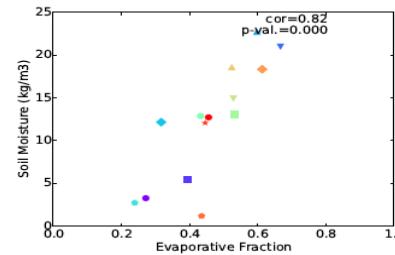
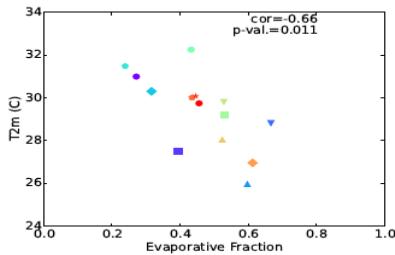
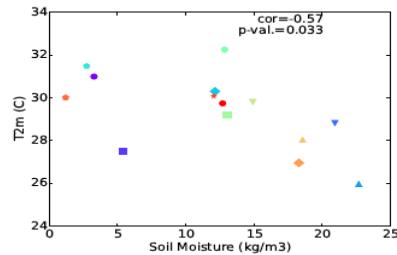
Based on ARM: Radflux Long

Model	Net-SWDN error (Wm-2)	Albedo error (Wm-2)	SWDN-clr error (Wm-2)	SWDN-cre error (Wm-2)
FGOALS-g2	22.65	-4.32	8.90	18.10
FGOALS-s2	41.72	-2.59	12.31	31.95
IPSL-CM5A-LR	30.39	5.46	12.27	12.71
IPSL-CM5B-LR	44.57	3.90	10.79	29.93
CanAM4	45.31	4.35	5.40	35.36
NorESM1-M	39.03	11.66	1.69	25.77
MPI-ESM-LR	22.99	-2.20	-0.60	25.77
MPI-ESM-MR	20.73	-2.15	-0.34	23.20
GISS-E2-R	-16.57	5.88	3.52	-26.06
bcc-csm1-1-m	21.78	-3.29	5.09	19.88
CESM1-CAM5	11.74	10.86	-2.06	2.97
IPSL-CM5A-MR	44.00	9.00	12.64	22.30
CSIRO-Mk3-6-0	57.53	15.60	6.77	34.91
MIROC5	40.18	13.13	4.24	22.82
ACCESS1-0	34.47	7.90	3.39	23.25
ACCESS1-3	47.95	16.25	2.26	29.56
BNU-ESM	59.93	26.19	4.61	29.05
GFDL-HIRAM-C360	26.35	5.42	2.22	18.72
GFDL-HIRAM-C180	16.50	-1.69	1.74	16.38
CCSM4	38.34	7.43	3.48	27.52
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Multi-Model Mean	32.68	6.26	4.84	21.54

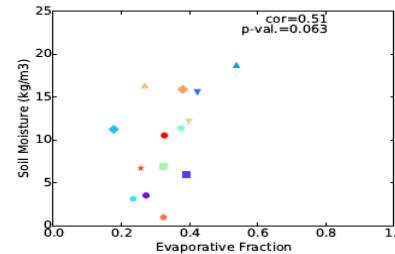
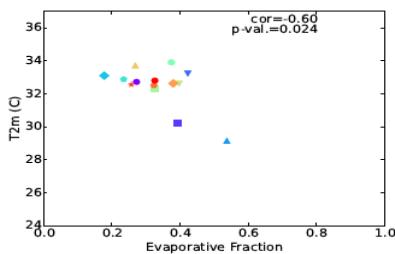
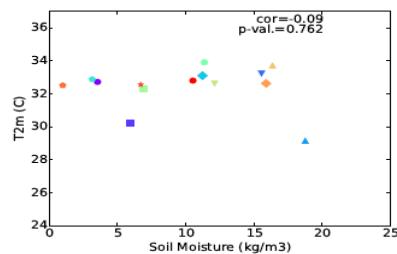
With out GISS : 35.14    6.27    4.9    23.92



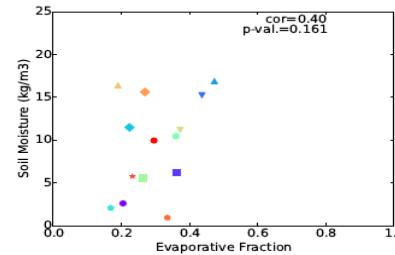
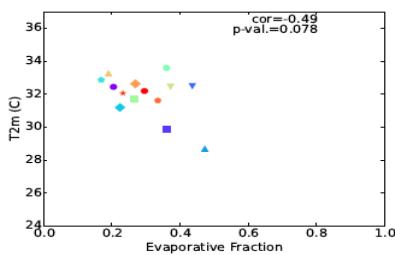
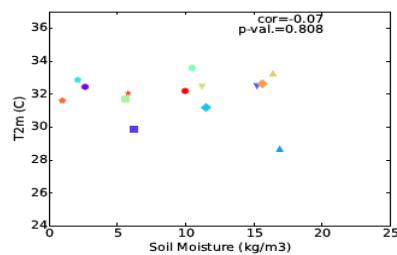
JUNE



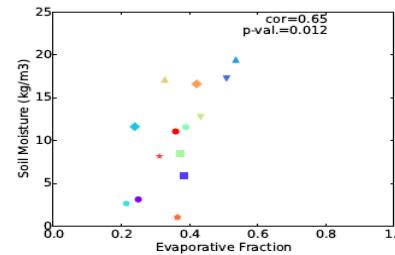
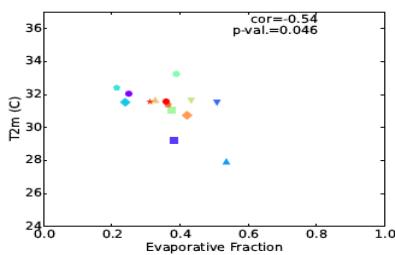
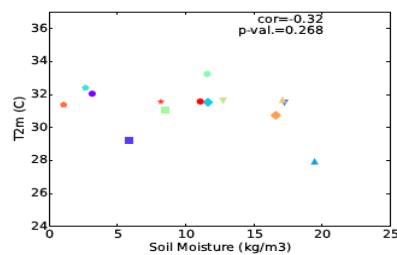
JULY



AUGUST



JJA



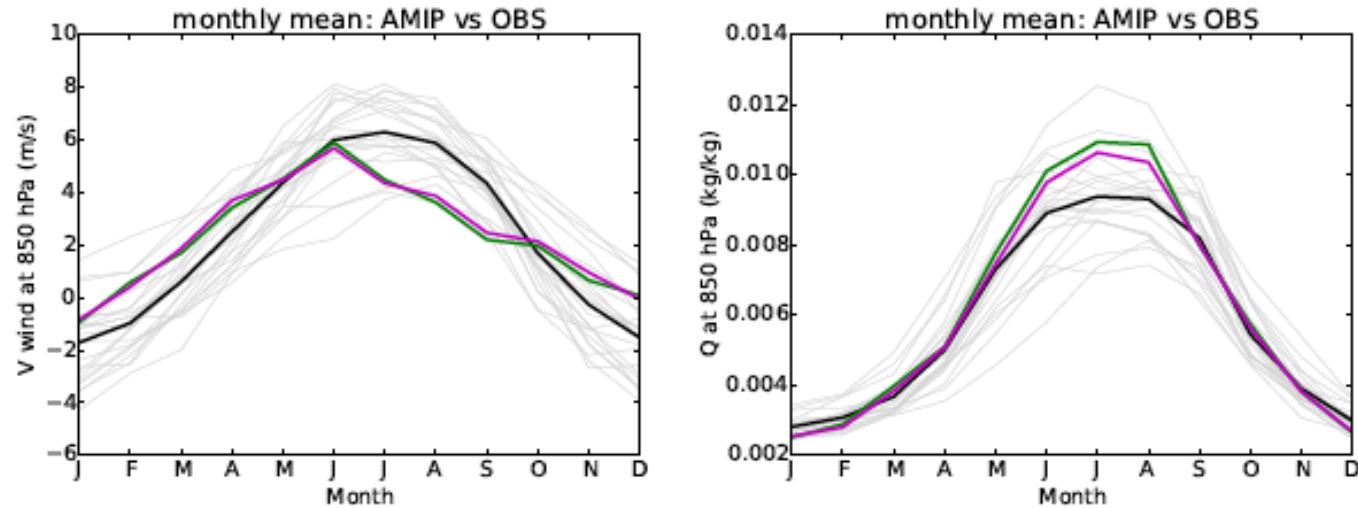
Soil moisture plays a central role in the partition of available energy at the land surface ( $EF=LH/(SH+LH)$ ).

Soil moisture and EF coupling strength varies by months.

In June, coupling is strongest.

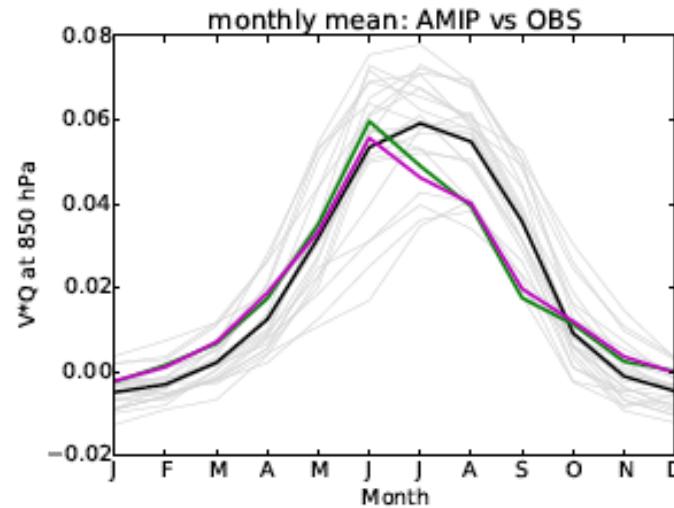


## Onto moisture transport: Magenta (ECMWF) Green (Continuous Forcing)



(a) V at 850 hPa

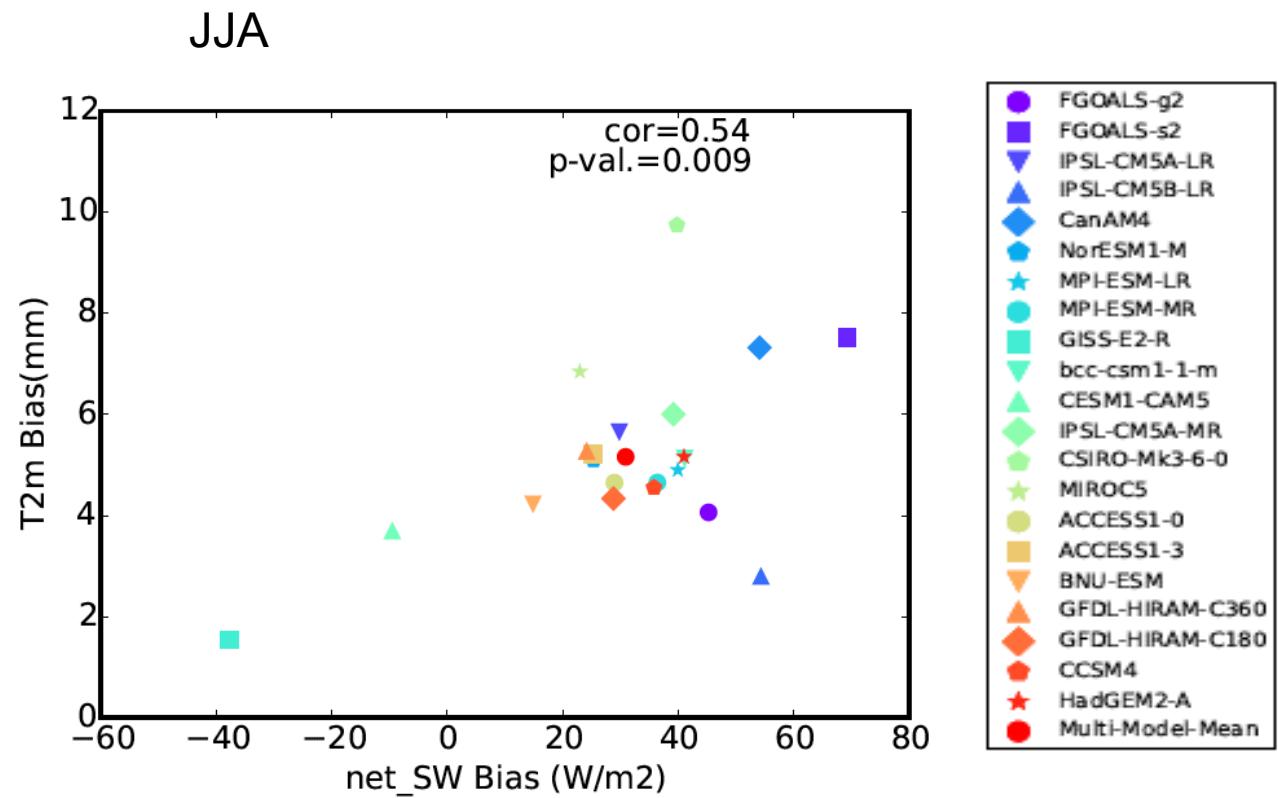
(b) q at 850 hPa



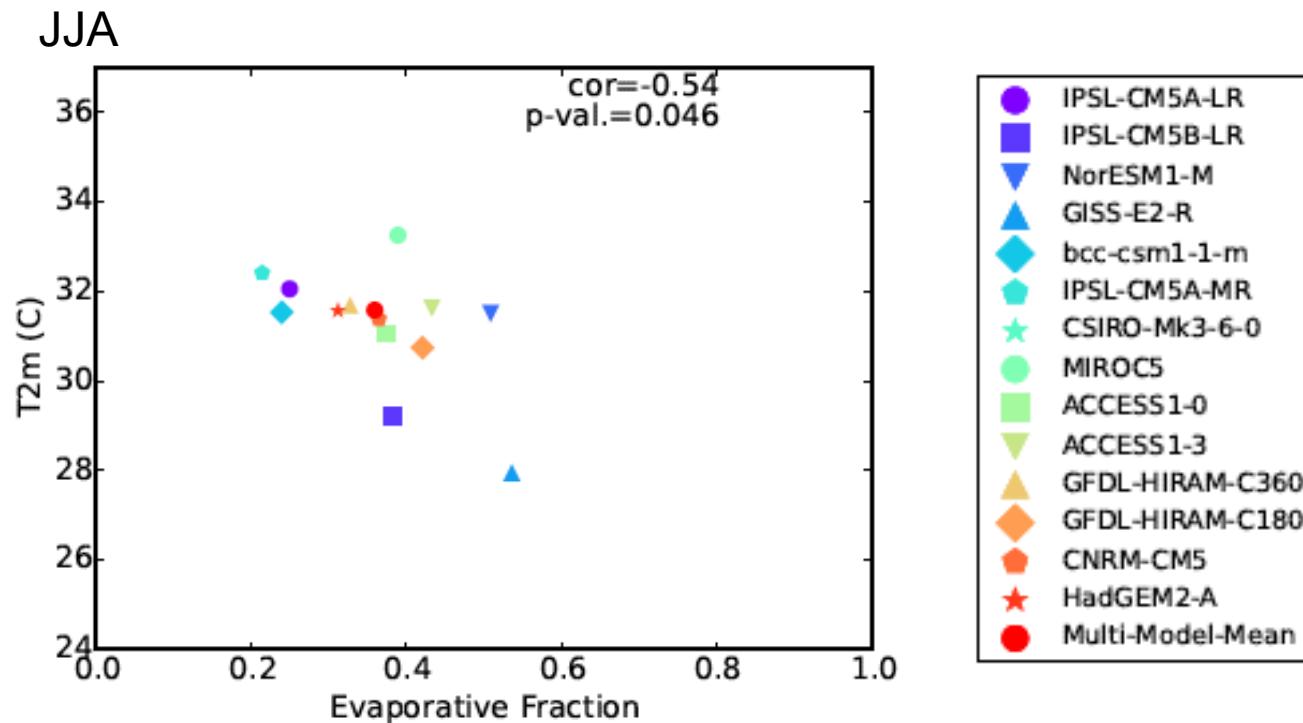
(c) Vq at 850 hPa



# Net SWDN bias correlates to T2m bias across models



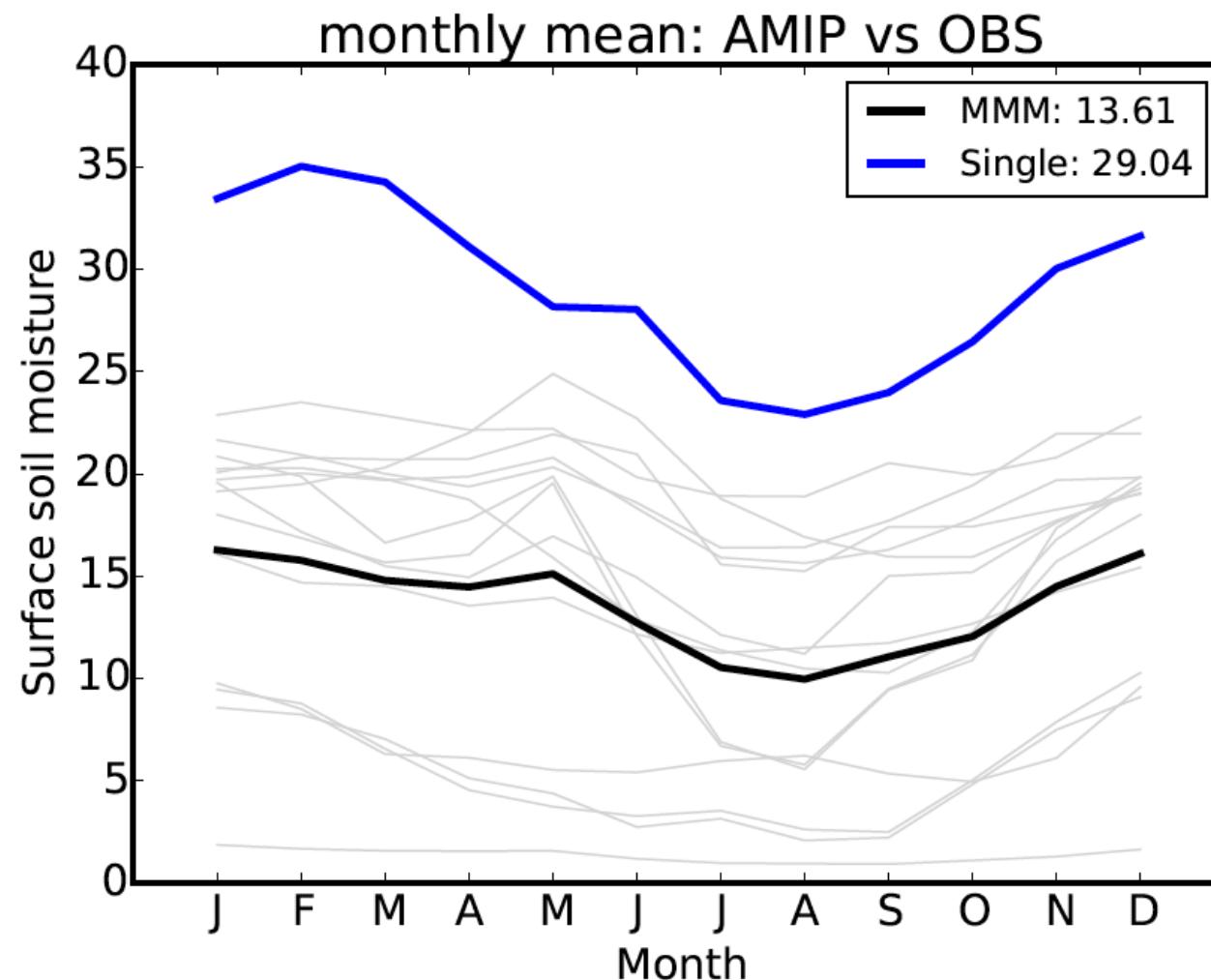
# EF correlates to T2m bias across models



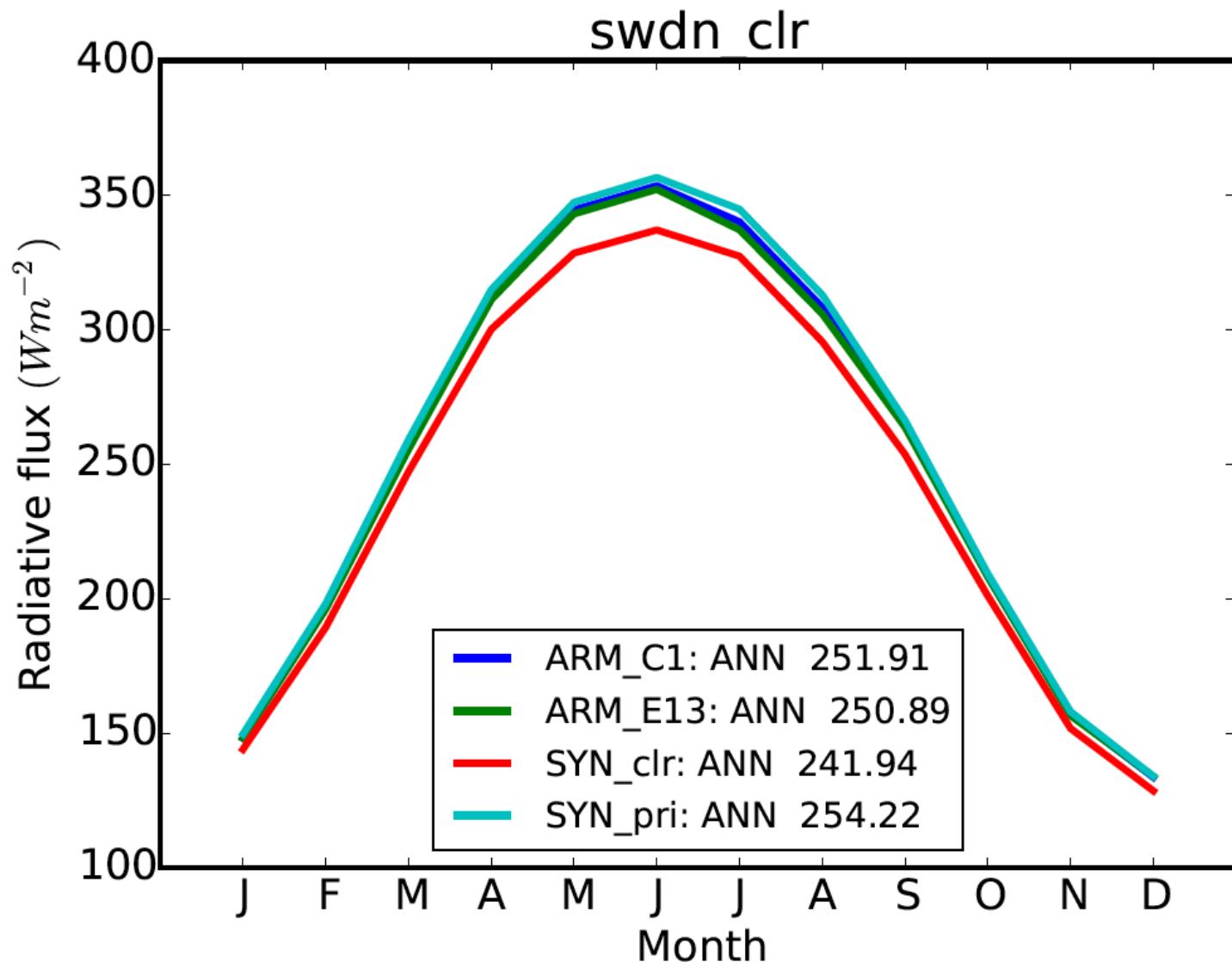
the partition of available energy at  
the land surface:  $EF=LH/(SH+LH)$



# Soil moisture



Clear-sky SW Down at two ARM sites E13 (36.66 N, 97.624 W) and C1 (36.60N, 97.485 W)



ARM Data stream:

sgpradflux1longC1 (1999~2011)  
Sgpradflux1longE13 (1997~2008)

CERES Data stream:

CERES\_SYN1deg (2000~2015)

